

SYNOPSIS

Urbanization and road-use determines *Calotropis procera* distribution in the eastern Indo-Gangetic plain, India

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Urbanization can be defined as local increase in the density of inhabitants coupled with increased per capita energy consumption and extensive modifications of the environment (including the microclimate) (Gilbert 1991; Vitousek et al. 1997). This process generates unstable ecosystems that depend on large inputs of energy, and where great amounts of waste materials are accumulated (Stearns 1970; McDonnell and Pickett 1990). Despite covering a small fraction of the Earth's surface (<5%), urban environments have a widespread influence on surrounding ecosystems (Vitousek et al. 1997; Goudie 2000). Fast growth of cities is promoting an increasing interest in urban ecosystems and in the impact of urbanization on distinct biotas (Vitousek et al. 1997; Grimm 1997). This ongoing growth of urban agglomerations leads to changes in biodiversity, including the loss of urban green cover, close vicinity forests, and other natural areas (Von der Lippe and Kowarik 2007, 2008). Ecological studies of such ecosystems are essential to reduce local and regional impacts of urbanization (Gilbert 1991; Niemelä 1999).

Under such human influence the rate and spatial scale of alien plant species has increased to unprecedented levels in the surroundings of urban agglomerations (Sharma and Raghubanshi 2009). Construction and development of roads network in close vicinity of urban areas have further mobilized movements of alien propagules. Recent researches suggested that roads act as corridors for spread of invasive non-native species into new landscapes (Sharma and Raghubanshi 2009; Kowarik and Von der Lippe 2007). Road verges provide suitable habitat and facilitate the exchange between plant populations and colonization (Beier and Noss

1998; Gonzalez et al. 1998), of propagules to habitats with a relatively high survival probability (Wenny 2001). But still there exists a gap how the distribution of alien species is influenced by urbanization and road use in complementarity.

Calotropis procera (Ait.) R. Br. is one species, which has been least studied with this perspective. *C. procera* is a alien/non-native woody (native of Israel) shrub and is widely distributed in degraded ecosystems of India (Saxena and Singh 1976). *C. procera* grows profusely without management and survives well under harsh conditions specifically along the road sides. But still no study quantifies how *C. procera* distribution is influenced by urbanization and road use.

The possible role of urbanization and road use in promoting *C. procera* spread is still unexplored. Here we intend to investigate that whether *C. procera* distribution is influenced by road-use type and distance from the urban agglomerations. So, further strategies for *C. procera* management can be designed accordingly for different road use types.

Calotropis procera (Ait.) R. Br. (Asclepiadaceae) is an erect spreading shrub, commonly 1–2 m in height (maximum 5.5 m), that reproduces by seeds. It's commonly known as Giant milkweed/Apple of Sodom and is native of Israel (Rahman and Wilcock 1991). *C. procera* leaves are opposite oblong-ovate to nearly orbicular, short-pointed to blunt at the apex with heart-shaped base, 7–18 cm long and 5–13 cm broad, slightly leathery, and have a fine coat of soft hairs. Flower clusters are umbelliform cymes that grow at or near the ends of twigs. Flowers are 1–1.5 cm long, fleshy and variable in color from white to pink, often spotted or tinged with purple (Howard 1989; Liogier 1995). The fruits are 8–12 cm long, inflated, obliquely ovoid follicles that split and invert when mature to release flat, brown seeds with a tuft of white hairs at one end (Howard

1989; Liogier 1995; Little 1974). Flowering and fruiting takes place throughout the year (Little 1974). Hundreds to thousands of seeds may be produced per plant each year. Seeds are dispersed by wind and may fly for several hundred yards in gentle breezes. Such levels of seed production are likely more than adequate to permit persistence and potential dominance. The successful invasion of *C. procera* can be attributed to its wide range of environmental adaptability and higher reproductive potential. It occurs as a major to intermediate weed of frequently disturbed areas and occurs along the road verges throughout India. It thrives best in disturbed urban lots and favors open habitat.

Richardson and Pyšek (2006) suggested that invasive alien species establish and proliferate across a range of environmental conditions and habitats. So, we sampled *C. procera* across two different road use types. We identified two road-use types: primary (high-use roads) and secondary (low-use roads) in the Indo-Gangetic plain of Uttar Pradesh, India. Road use categories were based on the subjective evaluation of the frequency of vehicle traffic (Sharma and Raghubanshi 2009). Sampling for *C. procera* was accomplished along the national highway between three cities (Allahabad, Varanasi, and Chandauli) and along the regional roads that crossed the central city (Varanasi) and extended from Jaunpur to (Barkacha) Mirzapur in India. We consider rural areas as large and isolated areas with low population density. The present study regards Chandauli, and Barkacha as rural areas and Allahabad and Varanasi as dense urban setups. Jaunpur considered as neo-urban since it's in the fast transition phase to urbanize.

Roadsides/verges have previously been used for rapid and large-scale surveys of invasive plants in many parts of the world (Henderson 1989, 1991a, b; Ullmann et al. 1995), because road verges are susceptible to invasion and accessible for sampling (Milton and Dean 1998), we designed our study accordingly. A drive-by survey method enabled us to make *Calotropis procera* counts along the road sides (Milton and Dean 1998). A belt transect of (10 m × 5,000 m) was laid just adjacent and parallel to the roads, i.e., roadsides/verges and *Calotropis procera* counts were made to determine the density within each block from a moving vehicle at the speed of 40 km/h (Milton and Dean 1998). Such blocks were laid consecutively for 200 km and for 150 km on the national and regional highway, respectively. *Calotropis procera* density was determined as total counts per unit area (10 m × 5,000 m).

The effect of road use on *Calotropis procera* density was analyzed using the Student's *t* test. Differences in *Calotropis procera* density among the urban and rural blocks (10 m × 5,000 m) were tested by Tukey's HSD test (at $P < 0.05$). Linear correlation regression was used wherever necessary. All statistical analyses were performed using the

SPSS (SPSS Inc., Chicago, USA) statistical package (SPSS 1997).

The mean *C. procera* density observed in a 10 m × 5,000 m belt transect, adjacent to the National highway and Regional highway was 248 and 172, respectively, which differed significantly ($t = -1.89$, $df = 51$, $P = 0.03$). Suggesting that with the increasing road use anthropogenic disturbance increase which subsequently makes the road verge more vulnerable to *C. procera* establishment and spread. High propagule output and dispersal attribute of *C. procera* which dominate the road verges may also ultimately lead to the invasion of adjacent land and further spread of this non-native plant across the landscape (Richardson et al. 2000; Von Holle and Simberloff 2005). Further with increasing road use the vehicle induced gust also increase which in turn guide tufted *C. procera* seed movements, leading to its spread.

Bubble plot of *C. procera* density along the National highway from one urban agglomeration (Allahabad) to other (Varanasi) which subsequently moves towards a rural environment (Chandauli) show *C. procera* trajectory from urban vicinity to rural setup (Fig. 1a). A similar pattern of *C. procera* density was also observed along the Regional highway which originated from a neo-urban area, passed through an urban agglomeration (Varanasi) and ended up in other rural region (Fig. 1b). The results reveal that the density of *C. procera* significantly decrease from the urban center to the rural area (for, e.g., Varanasi to Chandauli on a National highway: $R^2 = 0.72$; $P = 0.001$, Varanasi to Mirzapur on a Regional highway: $R^2 = 0.62$; $P = 0.004$). Studies show that urban centers are richer in plant species than surrounding areas as there is higher influx of alien species both from intentional and unintentional introductions (McKinney 2002, 2004; Kuhn et al. 2004; Hope et al. 2003). This might be the potential reason for *C. procera* concentrating more in the urban centers than rural. Higher densities in the vicinity of urban centers might be possible as urban areas are very much similar with respect to physical structures, materials and open space, resulting in consistent changes to the local physical and biological environment (Williams et al. 2009). Higher density of *C. procera* in Varanasi may also be attributed to its local religious importance. Sharma and Amritphale (2007) also reported similar pattern of *C. procera* counts in urban and rural areas of Ujjain in India.

High *C. procera* distribution in urban centers may cause health related problems as trichomes and pollens are toxic and may cause allergy (Sinha et al. 2001). Thus, vegetation of urban areas has societal value in sustaining public health and well-being (Ulrich 1984; Kuo and Sullivan 2001; Fuller et al. 2007). This need to be further explored with respect to *C. procera*.

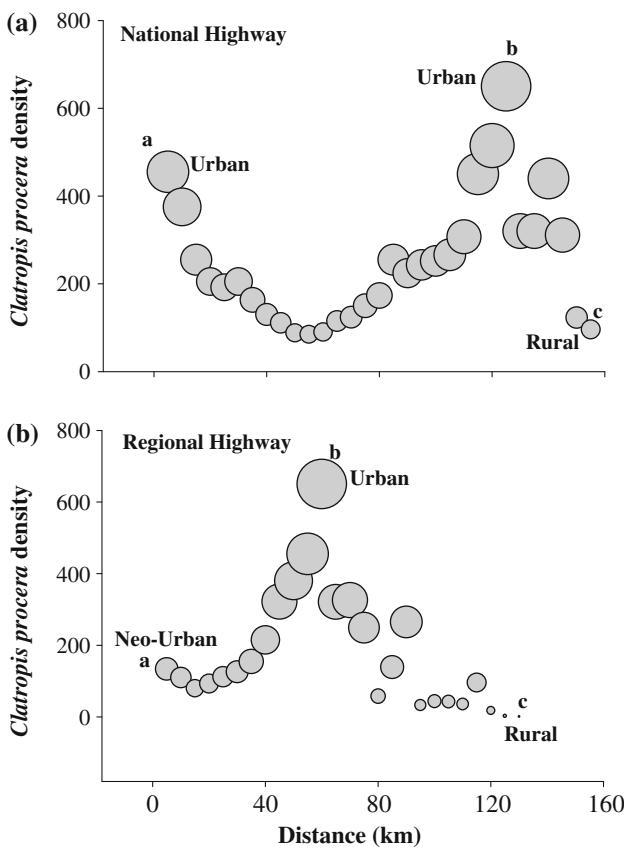


Fig. 1 Bubble plot of *C. procera* density along the **a** National highway and **b** Regional highway (Bubbles affixed with different letters are significantly different from each other according to Tukey's HSD test at $P < 0.05$). Size of the bubble represents relative *C. procera* density for each block

In general rural area possesses appreciable population of cattle's and therefore in rural areas grazing is more prevalent than urban areas (Maltsoglu 2008). The spreading phenomenon of *C. procera* towards rural areas may lead to decline of cattle population in rural areas as *C. procera* is toxic to cattle and cattle's grazing on this species may die (Parsons and Cuthbertson 1992; Smith 1995). The present study envisions the potential threat of *C. procera* encroachment toward the rural areas through road conduits. The study gives implication that *C. procera* management is needed in urban areas to avoid its drift. Despite the fact that some alien species may benefit from increased urbanization many conservationists and ecologists ignore the reality that rapid expansion of cities is a global phenomena and a critical problem that must be seriously tackled with this perspective.

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